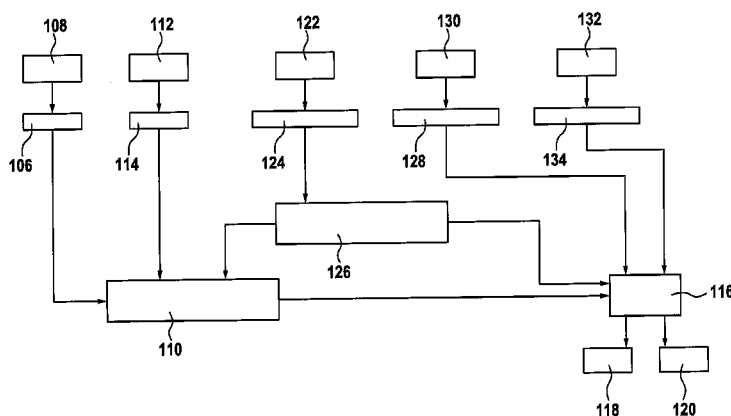


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(45) **Date of Patent:** *Sep. 29, 2015

- (58) **Field of Classification Search**
USPC 370/242; 455/436, 437, 438, 67.14,
455/456.1
See application file for complete search history.

- an information algorithm for informing a central network element (118) and/or at least one base station (120) of the mobile communication network about a conflict of physical cell identities when a conflict of physical cell identities is reported to the information algorithm; and initiating a reassignment of at least one physical cell identity.

16 Claims, 3 Drawing Sheets



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Fig. 1

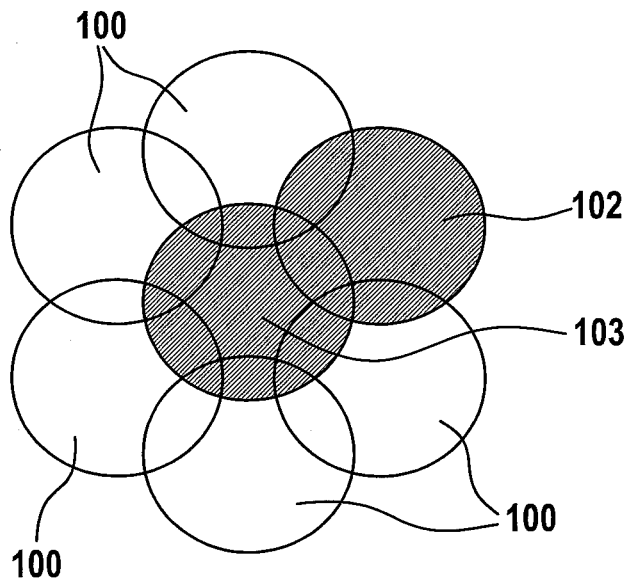


Fig. 2

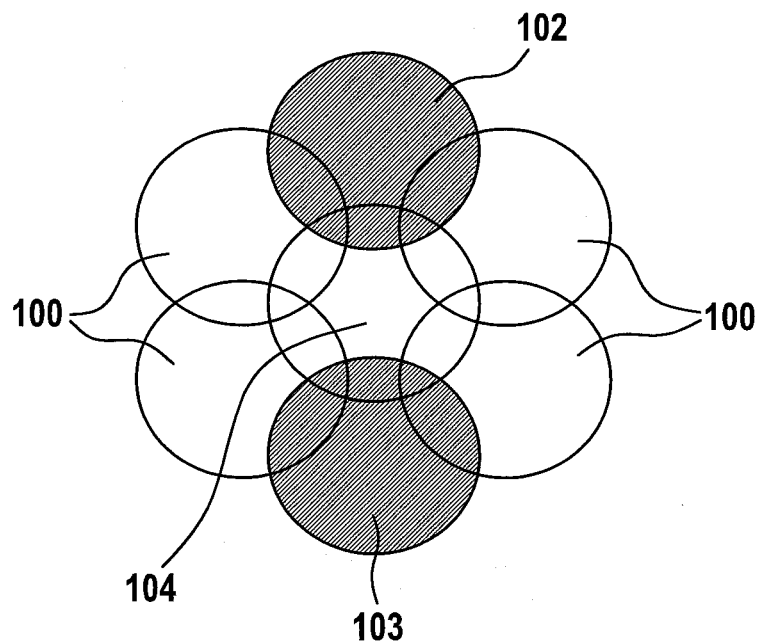


Fig. 3

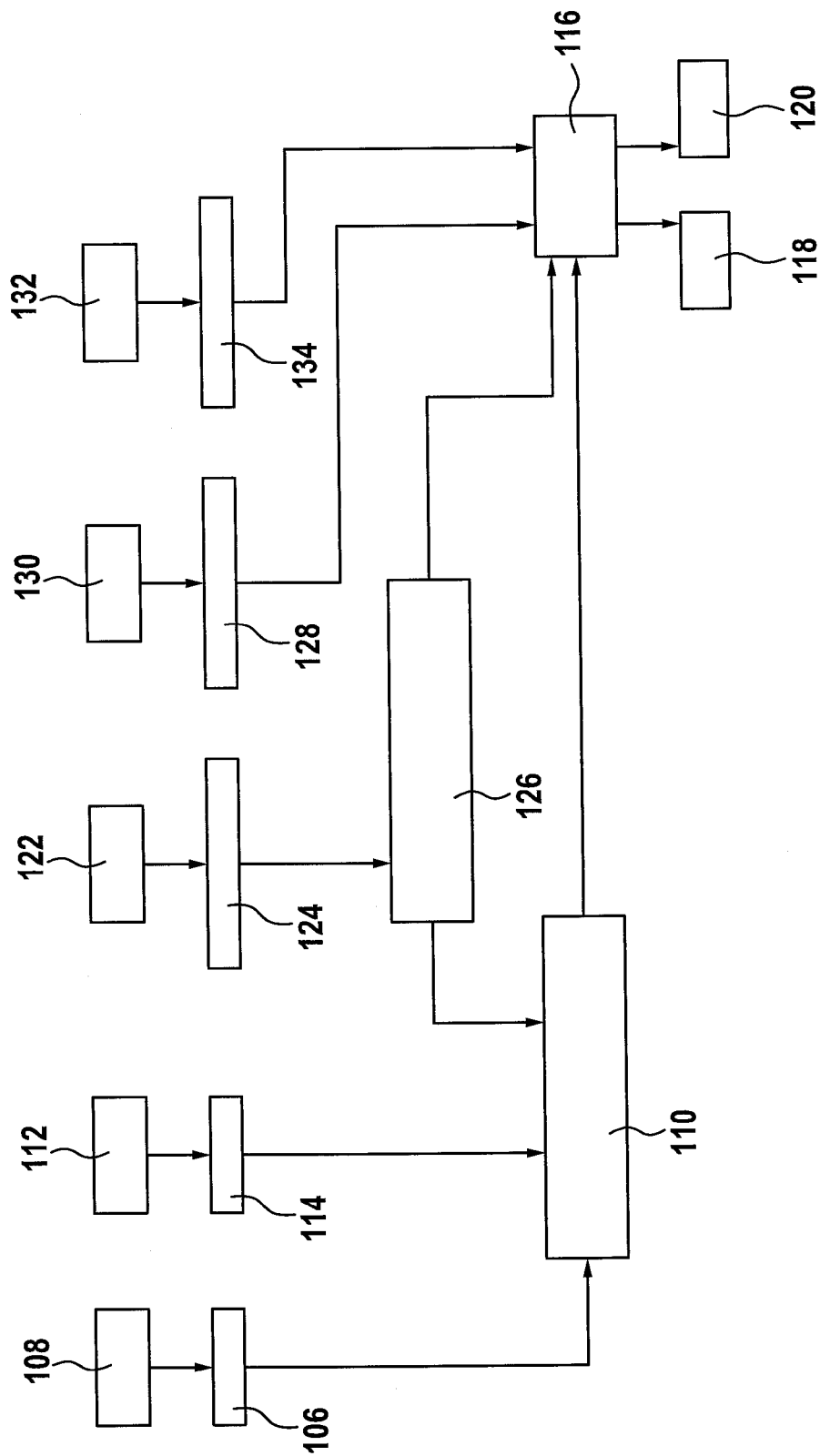


Fig. 4

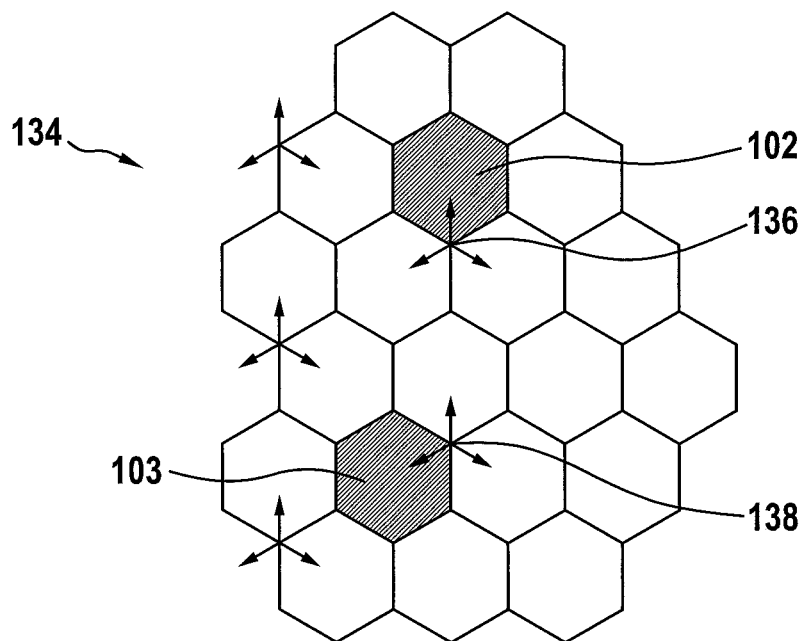
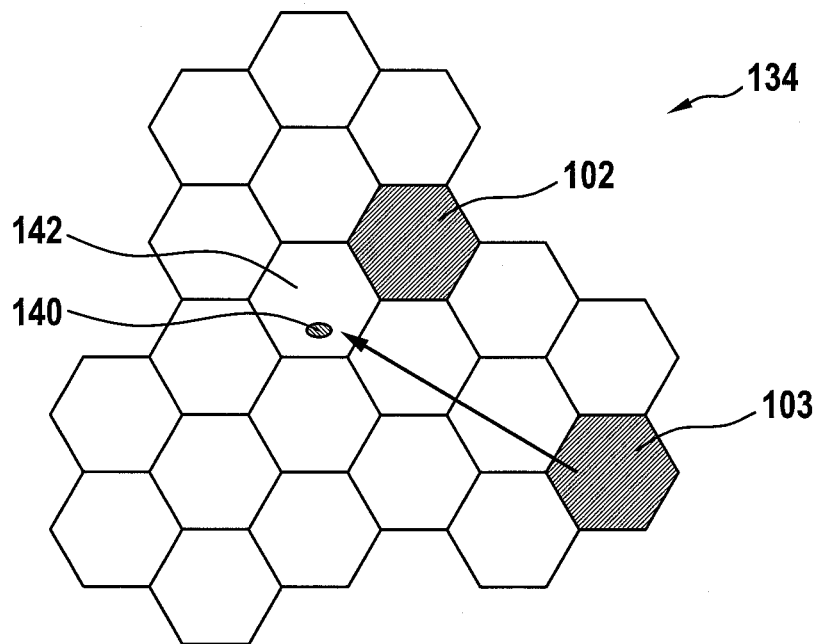


Fig. 5



METHOD FOR DETECTING PCI COLLISIONS

This application claims priority to and is a Continuation of U.S. application Ser. No. 13/380,645, filed Dec. 23, 2011, entitled METHOD FOR DETECTING PCI COLLISIONS, by Hajo Bakker, the disclosure of which is incorporated herein by reference in its entirety, which is a U.S. National Stage entry of International Application No. PCT/EP2010/058925 (International Filing Date of Jun. 23, 2010) which claims priority to European Application 09290493.7 (filed Jun. 26, 2009).

FIELD OF THE INVENTION

The present invention relates to a method of detecting a conflict of physical cell identities in wireless communication networks.

BACKGROUND AND RELATED ART

In wireless communication networks, e.g. 3GPP Long Term Evolution networks, every communication cell has a physical cell identity (PCI) and a cell global identity (CGI). While each CGI is dedicated to one single cell the number of PCIs being assigned to wireless communication network cells is limited to 504. So it cannot be excluded that two identical PCIs are selected for two different cells belonging to base stations of the wireless communication network being direct neighbors or being located in a short distance.

When one PCI is assigned to two different cells of the wireless communication network that are direct neighbors or located in a short distance, the communication of mobile devices with the wireless communication network in the proximity of the two cells with the same PCI can be disturbed.

It is therefore an object of the present invention to provide a method for avoiding conflicts of physical cell identities of different mobile communication cells.

SUMMARY OF THE INVENTION

This object is solved by the feature of claim 1. Preferred embodiments of the invention are described by the features of the dependent claims.

The present invention provides a computer implemented method of operating a base station of a wireless communication network. For avoiding conflicts of physical cell identities of different mobile communication cells a plurality of steps is performed as follows:

The number of missing context release messages during a handover procedure is compared with a first criterion. Usually, in the standard of 3GPP Long Term Evolution networks the context release message is a UE (User Equipment) context release message, the UE being preferably a mobile device. Preferably, the first criterion is a first threshold of missing context release messages per a time interval. This is advantageous for detecting if two different cells have the same PCI because during a handover procedure from a serving cell with a different PCI to a first neighbour cell, that is prepared for the handover, having the same PCI as a second neighbour cell, that is not prepared for the handover, the affected mobile device can try to execute a handover to the second neighbour cell because of the PCI conflict so that the context release message from the first neighbour cell is missing in the serving cell.

Cell Global Identities (CGIs) are in 3GPP Long Term Evolution networks unique identifiers for each radio cell of a

wireless communication network. Physical Cell Identities (PCTs) are in 3GPP Long Term Evolution networks non-unique identifiers for each radio cell of a wireless communication network.

The error rate of connection re-establishment messages is compared with a second criterion. Preferably, the second criterion is a second threshold of the error rate of connection re-establishment messages. This is advantageous because by analyzing the error rate of connection re-establishment messages a PCI conflict of two different cells can be detected. A connection re-establishment message is sent to a cell when the handover procedure of a mobile device was not successful. For example, a handover procedure of a mobile device is initiated by a serving cell with a different PCI to a first neighbour cell, that is prepared for the handover, with the same PCI as a second neighbour cell, that is not prepared for the handover. Because of the PCI conflict the first cell may be prepared for the handover of the mobile device while the mobile device executes a handover to the second unprepared cell with the same PCI as the first cell. Thus, the mobile device detects a handover failure because the second cell is not prepared for the handover. Then the mobile device sends a connection re-establishment message to the second cell.

If at least one of the first and the second criterion is fulfilled the cell global identity search algorithm is executed. The algorithm requests via an automatic neighbor relation measurement the cell global identity of at least one cell with the physical cell identity of the cell where the criterion was fulfilled. The automatic neighbor relation measurement is performed by at least one mobile device. The at least one mobile device reports the cell global identity of each cell with the physical cell identity requested by the algorithm. If at least two cells with different cell global identities and the same physical cell identity are detected the conflict of physical cell identities is reported to an information algorithm.

The information algorithm informs a central network element and/or at least one base station of the wireless communication network about the conflict of physical cell identities.

A reassignment of at least one physical cell identity is initiated. Preferably, one of the at least two base stations serving the at least two cells with the same physical cell identity changes the physical cell identity of the served cell by picking a new physical cell identity of a range of physical cell identities not including known physical cell identities of cells being located near the cell. Another possibility is that the central network element assigns a new physical cell identity to the cell by avoiding physical cell identities of cells being located near the cell.

In accordance with an embodiment of the invention, the method further comprises receiving the physical cell identities and the cell global identities of the cells served by the neighboring base stations by the base station. Additionally, the physical cell identities and the cell global identities of the cells served by the base station are reported to at least one neighboring base station of the wireless communication network. Preferably, this can be done via an interface connecting the base stations of the wireless communication network, e.g. X2 interface or an S1 interface, which are standard interfaces in 3GPP Long Term Evolution networks. If two different cells with different cell global identities have the same physical cell identity it is determined if detailed cell information is required. For example, two cells with the same physical cell identity and different cell global identities can be served by two neighboring base stations of the wireless communication network, the distance of the cells being big enough, i.e. the radio coverage areas of these cells do not overlap, to avoid a

conflict of the physical cell identities. The detailed information about the cells can help determining if a conflict of physical cell identities exists.

The detailed cell information contains preferably the position and the size of the cell, e.g. in terms of coverage area and main antenna lobe orientation. An unnecessary reassignment of at least one PCI can be avoided when the number of available PCIs is below a third threshold. Based on the detailed cell information a central network element and/or the base stations of the cells with the same PCIs determines if a reassignment of at least one PCI is necessary because of a PCI conflict. An unnecessary reassignment of at least one PCI is avoided when the number of available PCIs is below the third threshold and the detailed cell information indicates that the distance of the corresponding cells is big enough because the low number of available PCI renders a new conflict of PCIs probable.

When the number of available PCIs is above the third threshold no detailed cell information is required, a conflict of physical cell identities is reported to the information algorithm in this case.

If detailed cell information is required a message is sent to the base station serving the cell of that detailed cell information is required asking for the detailed cell information. Based on the detailed cell information it is determined if a physical cell identity conflict may exist. If a physical cell identity conflict may exist the cell global identity search algorithm is executed. Alternatively, the detailed cell information is sent by the base station serving the cell which may have a physical cell identity conflict to the neighbour base station without having asked detailed cell information. In this case the neighbour base station is able to determine if a physical cell identity conflict may exist. Finally, the detailed cell information can also be provided by the base stations to the central network element which can decide on a physical cell identity conflict.

In accordance with embodiments of the invention the method further comprises the detection of the loss of connections between the serving base station and a plurality of mobile devices. A loss of connection is detected when no uplink data is received without an initiated handover to a neighboring base station of the wireless communication network. When the number of lost connections fulfills a third criterion a physical cell identity conflict is reported to the information algorithm by the base station. Preferably, the third criterion is a fourth threshold of the number of lost connections between the base station and the plurality of mobile devices.

In accordance with embodiments of the invention the method further comprises requesting an automatic neighbor relation measurement. The automatic neighbor relation measurement is performed by a mobile device of the wireless communication network. The mobile device reports at least the physical cell identity and the cell global identity of the cell which has been specified by the serving cell. When a physical cell identity conflict is detected in the automatic neighbor relation measurement by the first base station the physical cell identity conflict is reported to the information algorithm by the base station.

In accordance with embodiments of the invention the reassignment of at least one physical cell identity is initiated by the central network element.

In accordance with embodiments of the invention the reassignment of at least one physical cell identity is initiated by the base station.

In accordance with embodiments of the invention the base station sends detailed cell information to a different base station that has requested the detailed cell information.

In accordance with embodiments of the invention the base station receives detailed cell information from a different base station that has sent the detailed cell information.

In accordance with embodiments of the invention the central network element receives detailed cell information from base stations that have sent the detailed cell information.

In accordance with embodiments of the invention the central network element is an operation and maintenance node.

A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of the above-described methods.

BRIEF DESCRIPTION OF THE DRAWINGS

The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventors to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

Some embodiments of methods and apparatus in accordance with embodiments of the present invention are now described, by way of example only, and with reference to the accompanying drawings, in which:

FIG. 1 shows a schematic view of a wireless communication network with a conflict of physical cell identities,

FIG. 2 shows a schematic view of a wireless communication network having a conflict of physical cell identities,

FIG. 3 shows a block diagram of a method for avoiding conflicts of physical cell identities in a wireless communication network,

FIG. 4 shows a schematic view of a plurality of cells of a wireless communication network where two cells have the same physical cell identity,

FIG. 5 shows a schematic view of a plurality of cells of a wireless communication network where a hotspot of a cell is located in a non-neighboring cell,

DETAILED DESCRIPTION OF THE FIGURES

FIG. 1 shows a schematic view of five cells **100** of a wireless communication network, each cell **100** having a different physical cell identity from another cell **100**. Further, FIG. 1 shows two neighboring cells **102**, **103** of the wireless communication network having the same physical cell identity. When a mobile device is located in the region where the two cells **102**, **103** overlap each other the conflict of physical

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cell identities can lead to a loss of the connection between a base station serving one of the two cells **102**, **103** and the mobile device is not able to decode the received information from the base station. Thus, the connection between the serving base station and the mobile device is lost.

FIG. 2 shows a schematic view of five cells **100** of a wireless communication network, each cell having a different physical cell identity from each other. Two cells **102**, **103** belong to the same wireless communication network having the same physical cell identity. The transmission range of the two cells **102**, **103** with the same physical cell identity do not overlap each other. The cells **102** and **103** neighbor the cell **104** which has a different PCI.

Because of the conflict of the same PCIs of the cells **102**, **103** a handover procedure of a mobile device being located in cell **104** may fail. For example, the handover request is sent from the base station serving cell **104** to the base station serving cell **102** although the handover should be performed to the neighbour cell **103**. The decision of the serving base station **104** to send out a handover request is based on the reported PCI from the mobile device. The handover request message is sent to the wrong cell **102** because of the conflict of physical cell identities. Thus, the base station serving the neighbour cell **103** to which the handover should be performed is not prepared to communicate with the mobile device. The base station serving cell **102** acknowledges the handover preparation procedure although the mobile device is not in the transmission range from cell **102**. As a result of this PCI conflict a context release message is not sent by the base station serving cell **102** to the base station serving cell **104** and the mobile device sends a connection re-establishment message to the unprepared base station serving neighbour cell **103**.

FIG. 3 shows a block diagram of an embodiment of the invention. In step **106** the number of missing context release messages **108** is compared with a first threshold. When the threshold is reached the cell global identity search algorithm **110** is executed in the serving cell. The error rate of connection re-establishment messages **112** is compared in step **114** with a second threshold. When the second threshold is reached the cell global identity search algorithm **110** is executed in the neighbour cell. Alternatively, the neighbour cell sends a failure indication message to the serving cell to start the cell global identity search algorithm **110** as well in the serving cell.

The cell global identity search algorithm **110** requests from mobile devices the cell global identity of at least one cell with the physical cell identity reported by the steps **106** and/or **114** to the cell global identity search algorithm **110** via an automatic neighbor relation measurement for this physical cell identity. If the cell global identity search algorithm **110** finds two different cell global identities of two different cells with the same physical cell identity a conflict of physical cell identities is reported to the information algorithm **116**. The information algorithm **116** informs a central network element **118** and/or the neighbour base stations **120** serving the cells causing the physical cell identity conflict.

The physical cell identities and the cell global identities of the cells served by the neighboring base stations **122** are received by the base station in step **124**. In step **124** additionally the physical cell identities and the cell global identities of the neighbouring cells of the served cells of the neighbour base station are reported to the base station of the wireless communication network.

In step **126** it is determined if detailed cell information is required when at least two cells have the same physical cell identity. No additional cell information is required in network

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configurations where a sufficient number of physical cell identities is available to be assigned to one of the cells causing the physical cell identity conflict. If no detailed cell information is required the physical cell identity conflict is reported to the information algorithm **116**.

Detailed cell information is required when the number of available physical cell identities is under a third threshold so that a reassignment of a physical cell identity could cause a new physical cell identity conflict. For avoiding the reassignment of a physical cell identity although there is no physical cell identity conflict, detailed cell information about the cells causing the physical cell identity conflict is requested. The detailed cell information can for example comprise the size and the position of the cell which can be provided in terms of cell type or coverage area, coordinates and main antenna lobe orientation. The detailed cell information is exchanged between the base stations via an X2 or S1 interface. Based on the detailed cell information it is determined if the cell global identity search algorithm **110** is executed.

In step **128** lost connections **130** between the base station and mobile devices are detected. Lost connections can be caused by a physical cell identity conflict. For example, when two neighboring cells have the same physical cell identity, see FIG. 1. If the number of lost connections **130** reaches a fourth threshold the information algorithm **116** is executed.

An automatic neighbor relation measurement **132** is requested in step **134**. The automatic neighbor relation measurement is performed by a mobile device that reports every physical cell identity and cell global identity in the transmission range of the mobile device to the base station. When the same physical cell identity is assigned to two cells with different cell global identities a physical cell identity conflict is reported to the information algorithm **116**.

Every time the information algorithm **116** is executed the central network element **118** and the base stations serving the cells with the same physical cell identities are informed about a conflict of physical cell identities. When the central network element and the base stations are informed about a conflict of physical cell identities the central network element may decide if a reassignment of a physical cell identity of the cells causing the physical cell identity conflict is performed from the central network element **118** or if the reassignment is performed by one of the base stations **120** serving the cells causing the physical cell identity conflict.

FIG. 4 shows a schematic view of a plurality of cells **134** of a wireless communication network comprising two cells with the same physical cell identity **102** and **103**. The two cells **102** and **103** are served by two neighboring base stations **136** and **138**. Although two neighboring base stations **136** and **138** serve two cells **102** and **103** with the same physical cell identity it is not mandatory that there exists a conflict of physical cell identities because the distance between the cells **102** and **103** can be big enough to avoid physical cell identity conflicts. If the number of available physical cell identities for a reassignment of the physical cell identity of cell **102** or **103** is below a threshold, detailed cell information of the cells **102** and **103** is required to determine if a conflict of physical cell identities exists. If the number of available physical cell identities is above the threshold a new physical cell identity can be assigned to cell **102** or **103** without requesting detailed cell information.

The detailed cell information comprises information of the size and the position of the cell which can be provided in terms of cell type or coverage area, coordinates and main antenna lobe orientation. Based on this detailed cell information it is determined if a reassignment of a physical cell identity of the cell **102** or **103** is necessary to avoid a physical

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cell identity conflict. Usually this is the case for small cells or for the deployment of many small cells in an environment of large overlay cells.

FIG. 5 shows a schematic view of a wireless communication network 134 comprising two cells 102 and 103 with the same physical cell identity. A hotspot 140 of the cell 103 is located in a neighboring cell 142 of cell 102. The hotspot can be caused by real radio conditions in special topological environments. For example, the base station of cell 103 may be located at a hillside such that a hotspot of the cell may be generated on the other side of the valley at another hillside in cell 142.

This hotspot may cause a conflict of physical cell identities although the distance between the cells 102 and 103 seems to be big enough to avoid a conflict of physical cell identities.

This conflict of physical cell identities can be detected by analyzing the handover procedures or the detection of lost connections with mobile devices, see FIG. 3.

LIST OF REFERENCE NUMERALS

100 cell of the wireless communication network
 102 cell with the same PCI as 103
 103 cell with the same PCI as 102
 104 cell located between 102 and 103
 106 comparing 108 with first threshold
 108 number of missing context release messages
 110 cell global identity search algorithm
 112 error rate of connection re-establishment messages
 114 comparing 112 with second threshold
 116 information algorithm
 118 central network element
 120 base station serving 102 and 103
 122 physical cell identities and cell global identities of neighboring base stations
 124 receiving 122
 126 detailed cell information
 128 detecting 130
 130 lost connections between a mobile device and a base station of the wireless communication network
 132 automatic neighbor relation measurement
 134 plurality of cells of the wireless communication network
 136 base station serving cell 102
 138 base station serving cell 103
 140 hotspot of cell 103
 142 neighboring cell of cell 102

The invention claimed is:

1. A method for correcting a physical cell identity (PCI) conflict in a wireless communication network, wherein the method comprises:

performing a cell global identity search, wherein the cell global identity of at least one cell with a specific physical cell identity is requested at a base station via an automatic neighbor relation measurement performed by at least one mobile device and wherein a conflict of physical cell identities is detected when for the specific physical cell identity at least two cell global identities are found; and
 initiating a reassignment of at least one physical cell identity.

2. The method of claim 1, further comprising:
 comparing a number of missing context release messages with a first criterion; and
 comparing the error rate of connection reestablishment messages with a second criterion.

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3. The method of claim 1, further comprising:

informing, via an information algorithm, a central network element and at least one base station of the mobile communication network about a conflict of physical cell identities when a conflict of physical cell identities is reported to the information algorithm.

4. The method of claim 1, wherein a connection reestablishment message is sent to a cell when a handover procedure of a mobile device is not successful.

5. The method of claim 1, wherein the reassignment of at least one physical cell identity occurs when one of at least two base stations serving the at least two cells with the same physical identity changes the physical cell identity of the served cell by picking a new physical cell identity of a range of new physical cell identities not including known physical cell identities of cells located near the cell.

6. The method of claim 1, wherein, based on the detailed cell information, a central network element or the base stations of the cells with the same physical cell identities determine if a reassignment of a least one PCI is necessary due to a PCI conflict.

7. A base station, of a wireless communication network, comprising at least one processor configured to:

perform a cell global identity (PCI) search, wherein the cell global identity of at least one cell with a specific physical cell identity is requested at a base station via an automatic neighbor relation measurement performed by at least one mobile device and wherein a conflict of physical cell identities is detected when for the specific physical cell identity at least two cell global identities are found; and

initiate a reassignment of at least one physical cell identity.

8. The base station of claim 7, the at least one processor being further configured to:

compare a number of missing context release messages with a first criterion; and

compare the error rate of connection reestablishment messages with a second criterion.

9. The base station of claim 7, the at least one processor being further configured to:

change the physical identity of one of two cells having the same physical cell identity, the cells being simultaneously served by the base station and at least one other base station, by picking a new physical cell identity of a range of physical cell identities not including known physical cell identities of cells located near the cell for which the identity is changed.

10. The base station of claim 7, the at least one processor being further configured to:

determine, based on the detailed cell information, if a reassignment of a least one PCI is necessary due to a PCI conflict.

11. A method implemented by a non-transitory computer readable storage medium, in which a program is saved, the program comprising instructions which, when they are executed in a programmable device, perform the method, the method comprising:

performing a cell global identity search, wherein the cell global identity of at least one cell with a specific physical cell identity is requested at a base station via an automatic neighbor relation measurement performed by at least one mobile device and wherein a conflict of physical cell identities is detected when for the specific physical cell identity at least two cell global identities are found; and

initiating a reassignment of at least one physical cell identity (PCI).

12. The method of claim **11**, further comprising:
comparing a number of missing context release messages
with a first criterion; and
comparing the error rate of connection reestablishment
messages with a second criterion. 5

13. The method of claim **11**, further comprising:
informing, via an information algorithm, a central network
element and at least one base station of the mobile com-
munication network about a conflict of physical cell
identities when a conflict of physical cell identities is 10
reported to the information algorithm.

14. The method of claim **11**, wherein a connection reestab-
lishment message is sent to a cell when a handover procedure
of a mobile device is not successful.

15. The method of claim **11**, wherein the reassignment of at 15
least one physical cell identity occurs when one of at least two
base stations serving the at least two cells with the same
physical identity changes the physical cell identity of the
served cell by picking a new physical cell identity of a range
of new physical cell identities not including known physical 20
cell identities of cells located near the cell.

16. The method of claim **11**, wherein, based on the detailed
cell information, a central network element or the base sta-
tions of the cells with the same physical cell identities deter-
mine if a reassignment of a least one PCI is necessary due to 25
a PCI conflict.

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